US009638500B1

(12) United States Patent
Blyskal et al.

(10) Patent No.: US 9,638,500 B1
(45) Date of Patent: May 2, 2017

(54) **FRAGMENTATION WARHEAD WITH FLEXIBLE LINER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 429 days.

(21) Appl. No.: **14/267,067**

(22) Filed: **May 1, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/824,554, filed on May 17, 2013.

(51) **Int. Cl.**

F42B 10/00	(2006.01)
F42B 12/00	(2006.01)
F42B 30/00	(2006.01)
F42B 12/22	(2006.01)
F42B 12/72	(2006.01)

(52) **U.S. Cl.**
CPC ***F42B 12/22*** (2013.01); ***F42B 12/72*** (2013.01)

(58) **Field of Classification Search**
CPC F42B 12/22; F42B 12/72
USPC 102/306–310, 475, 476, 506, 389
See application file for complete search history.

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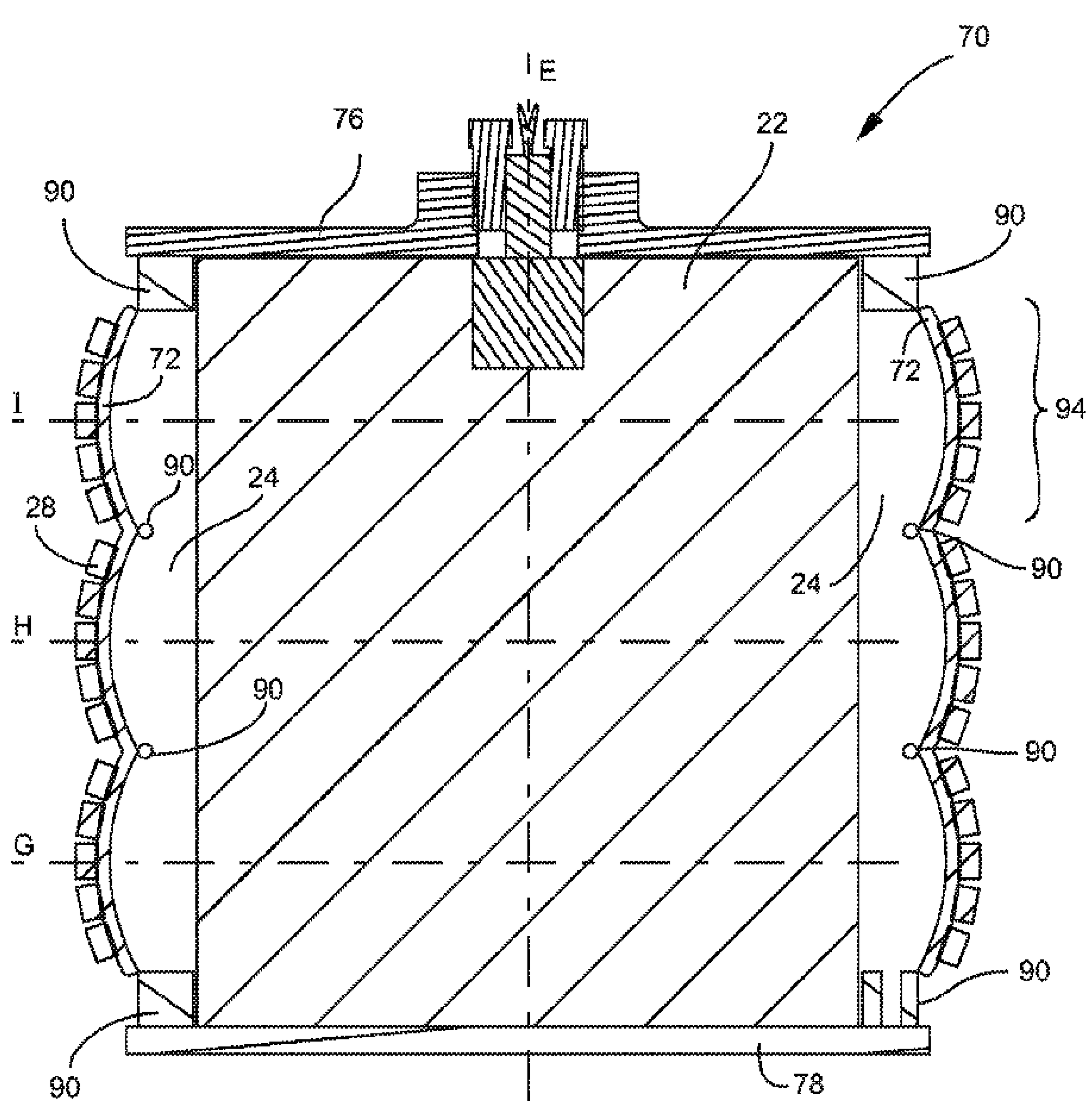
(57) **ABSTRACT**

A fragmentation warhead with a flexible liner enables increased control of the warhead's fragmentation pattern. The flexible liner is fixed to a rigid portion of the warhead housing. Explosive material is contained in the housing. A fluid is disposed between the explosive material and the flexible liner to function as a shock transition material. The fluid is contiguous with and bears on an inner surface of the flexible liner. A plurality of rigid fragments or a plurality of explosively formed projectile (EFP) liners are fixed to an outer surface of the flexible liner opposite the fluid. Initiation of the explosive material propels the fragments or EFP liners in directions that may be varied by varying the shape of the flexible liner.

23 Claims, 10 Drawing Sheets



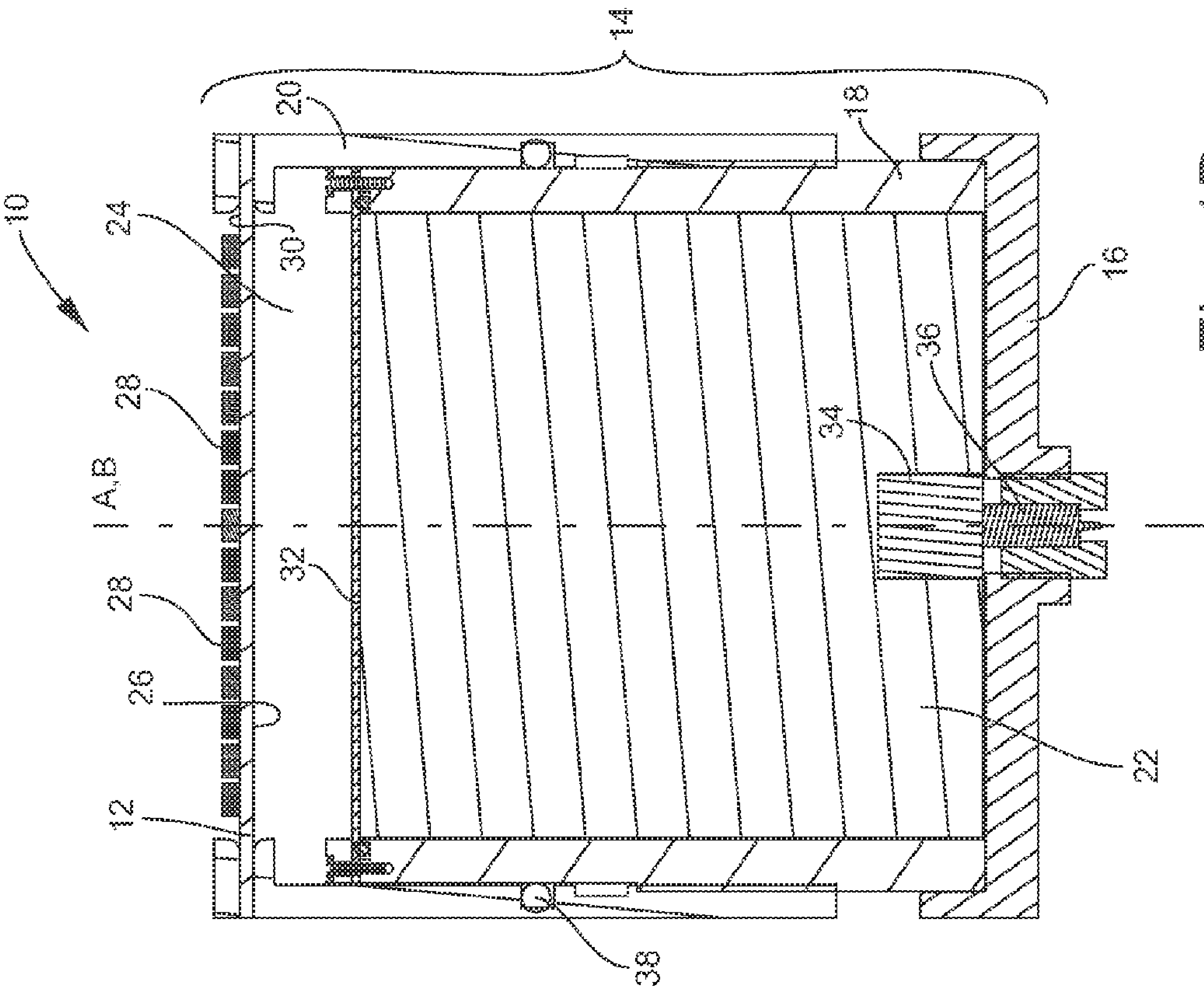


Fig. 1B

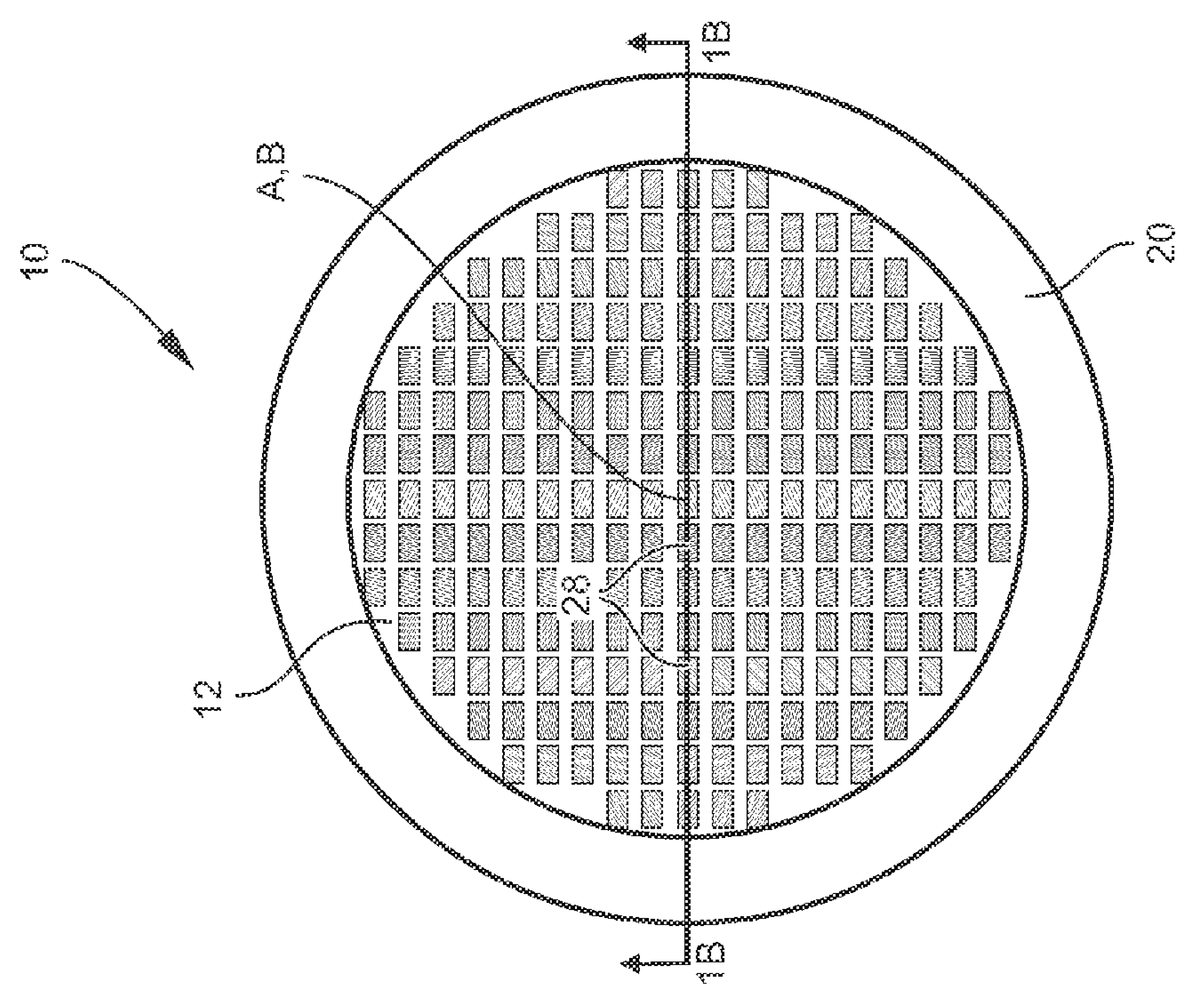


Fig. 1A

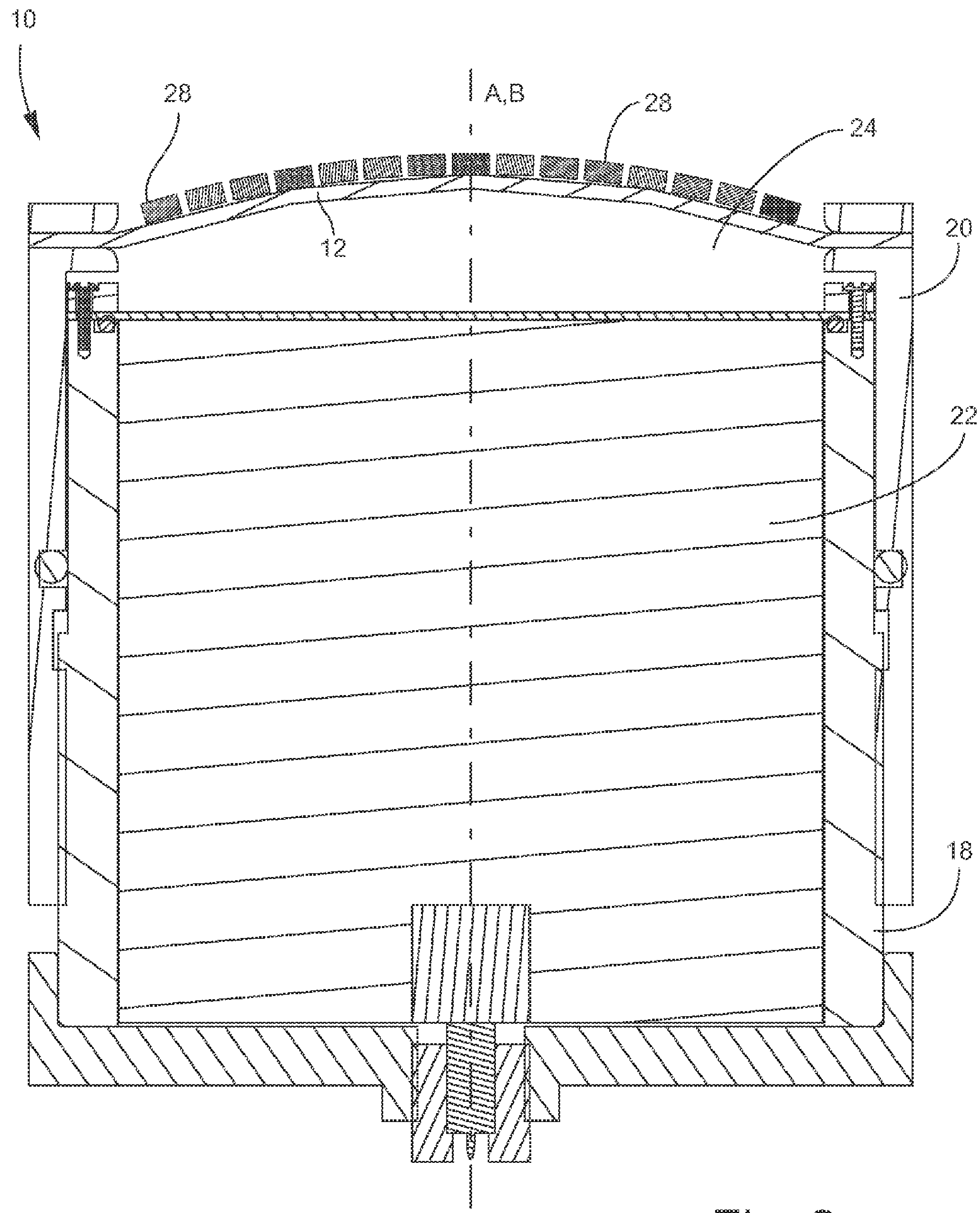


Fig. 2

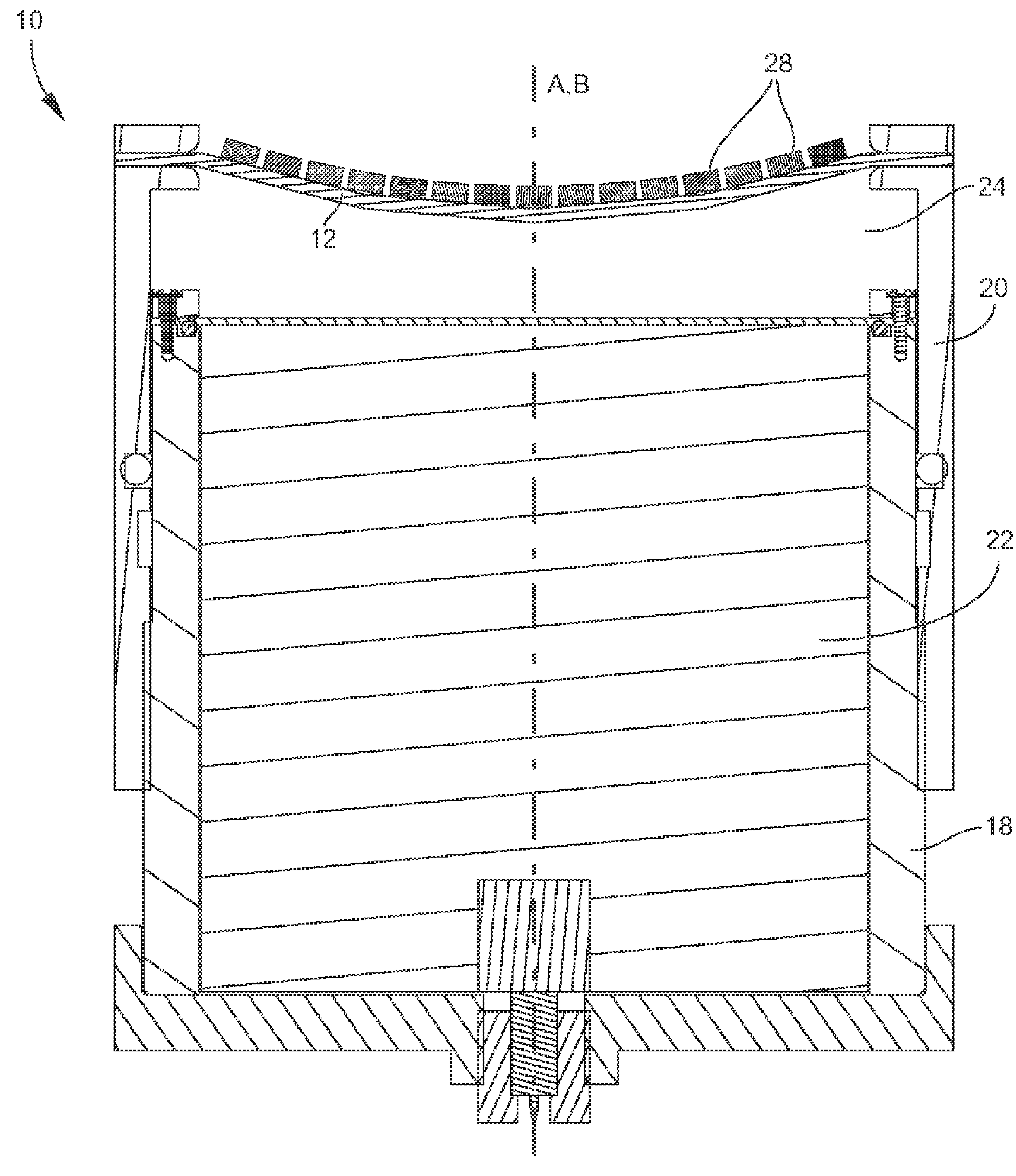


Fig. 3

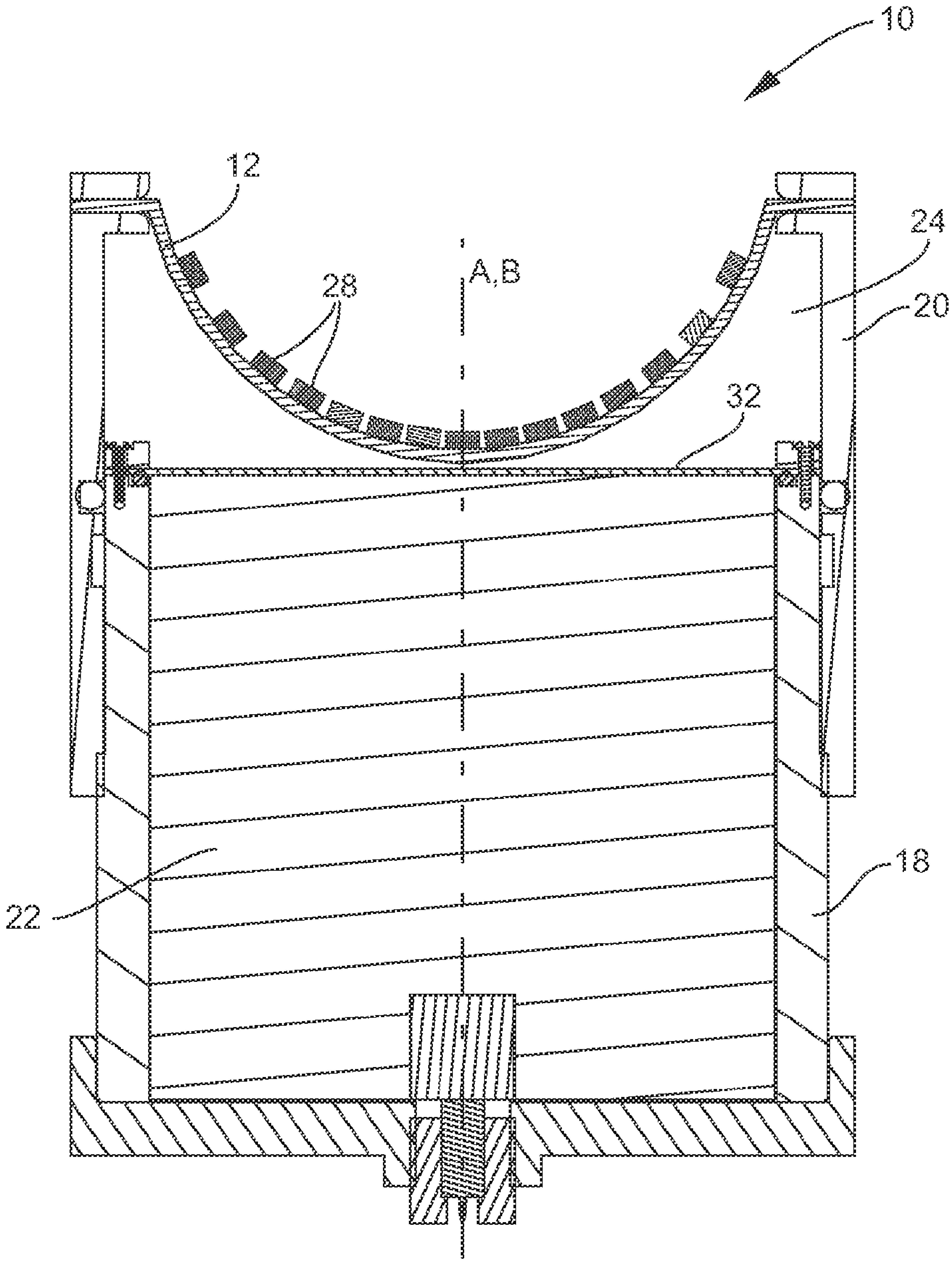


Fig. 4

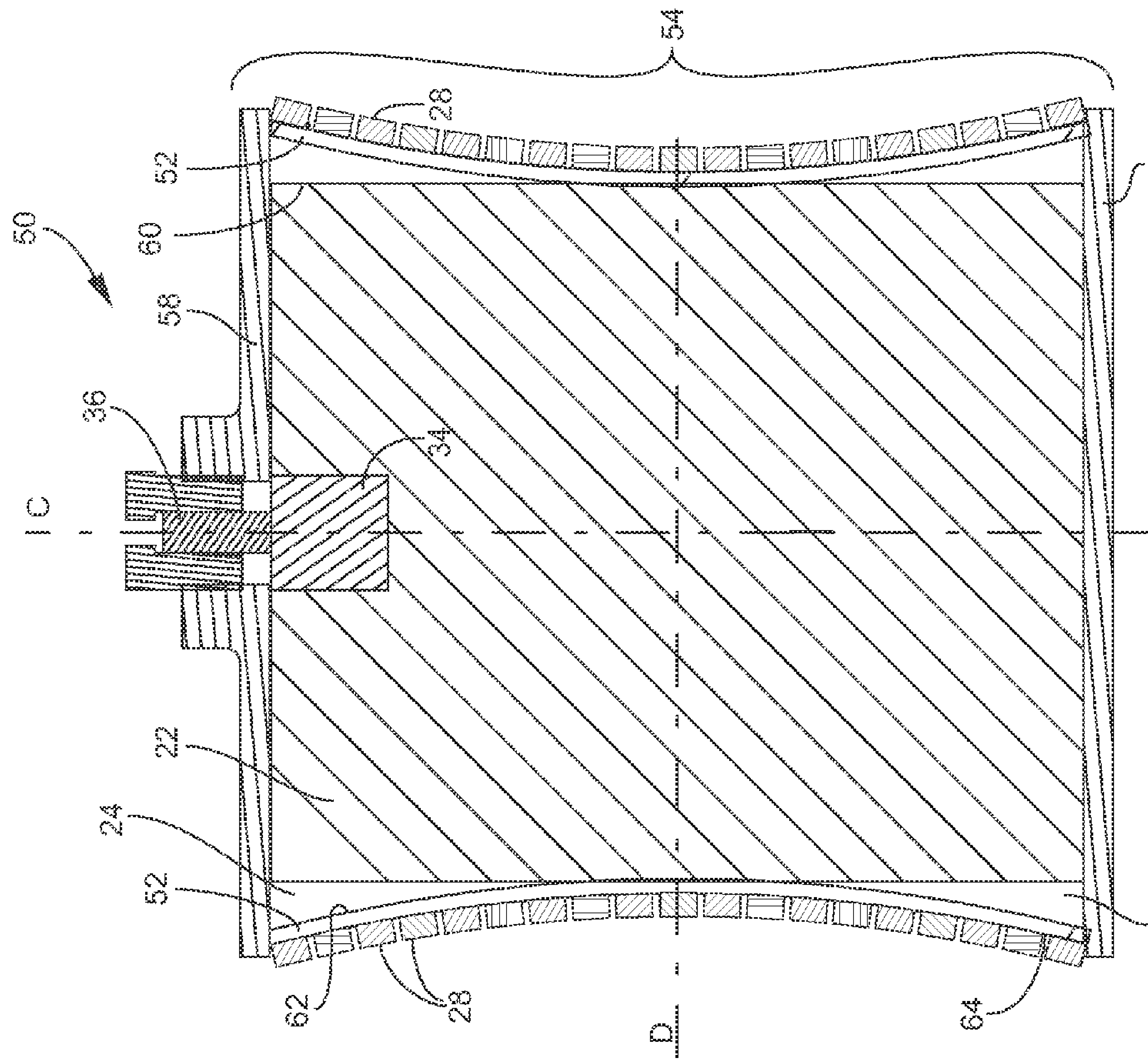


Fig. 5B

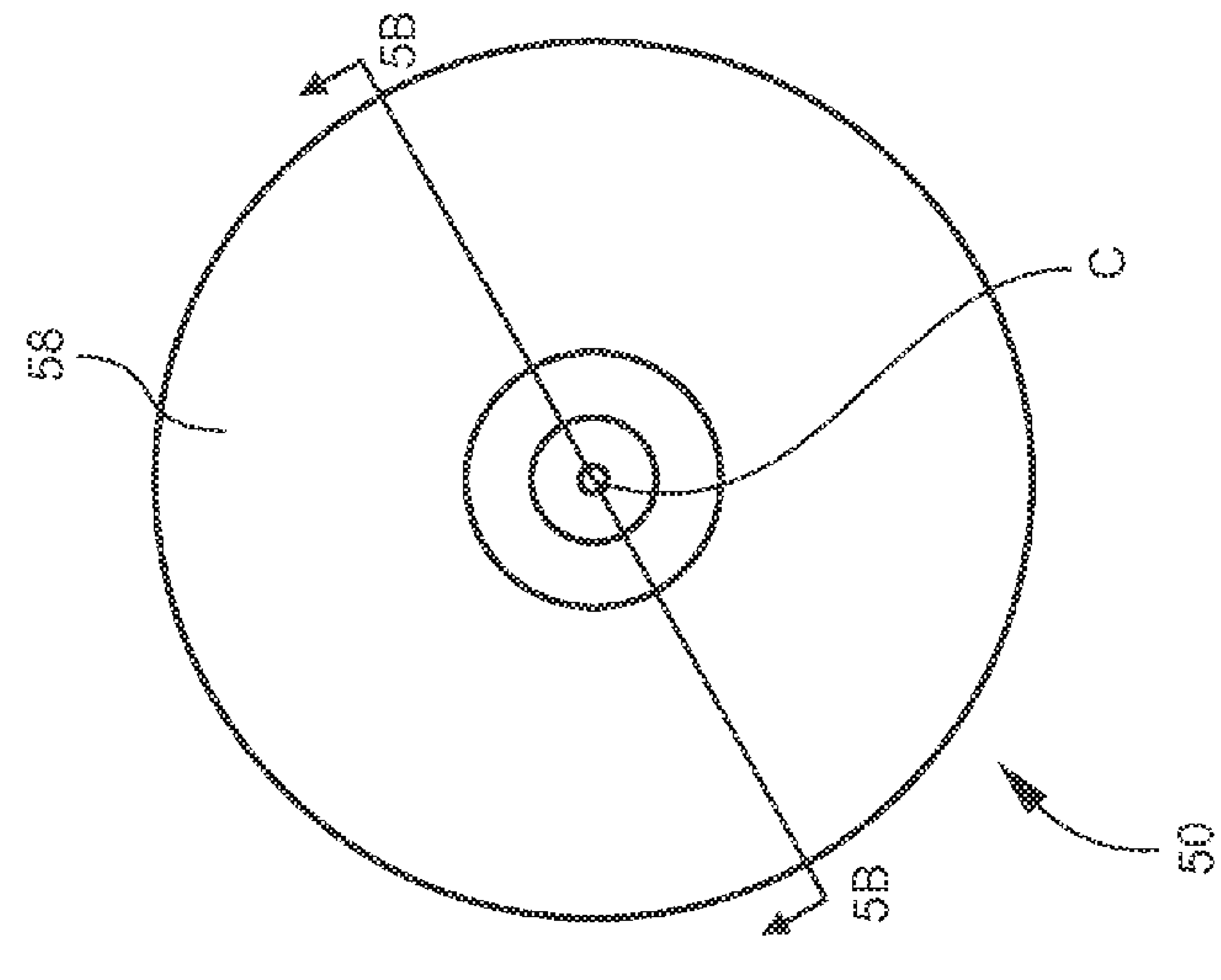


Fig. 5A

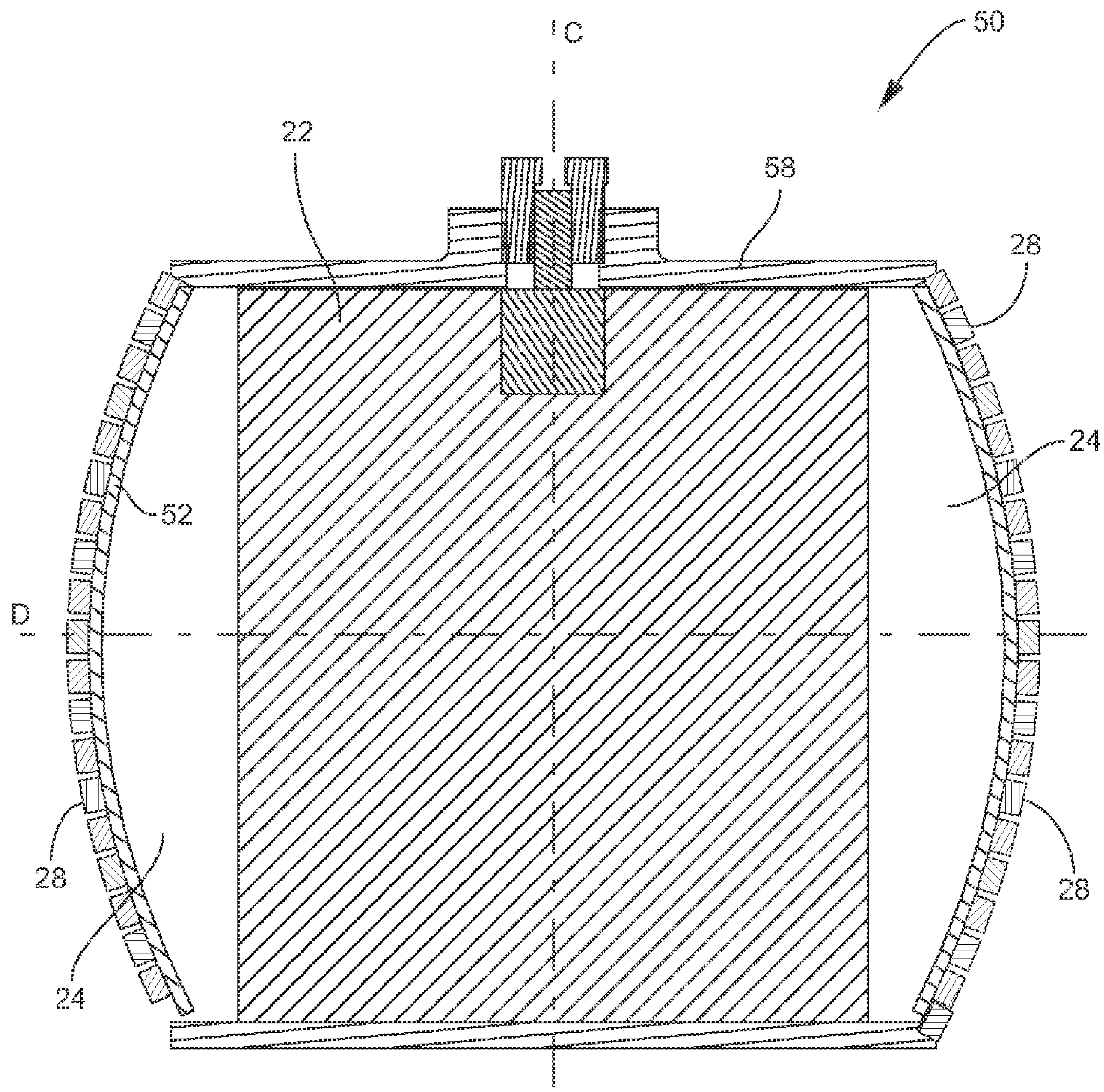


Fig. 6

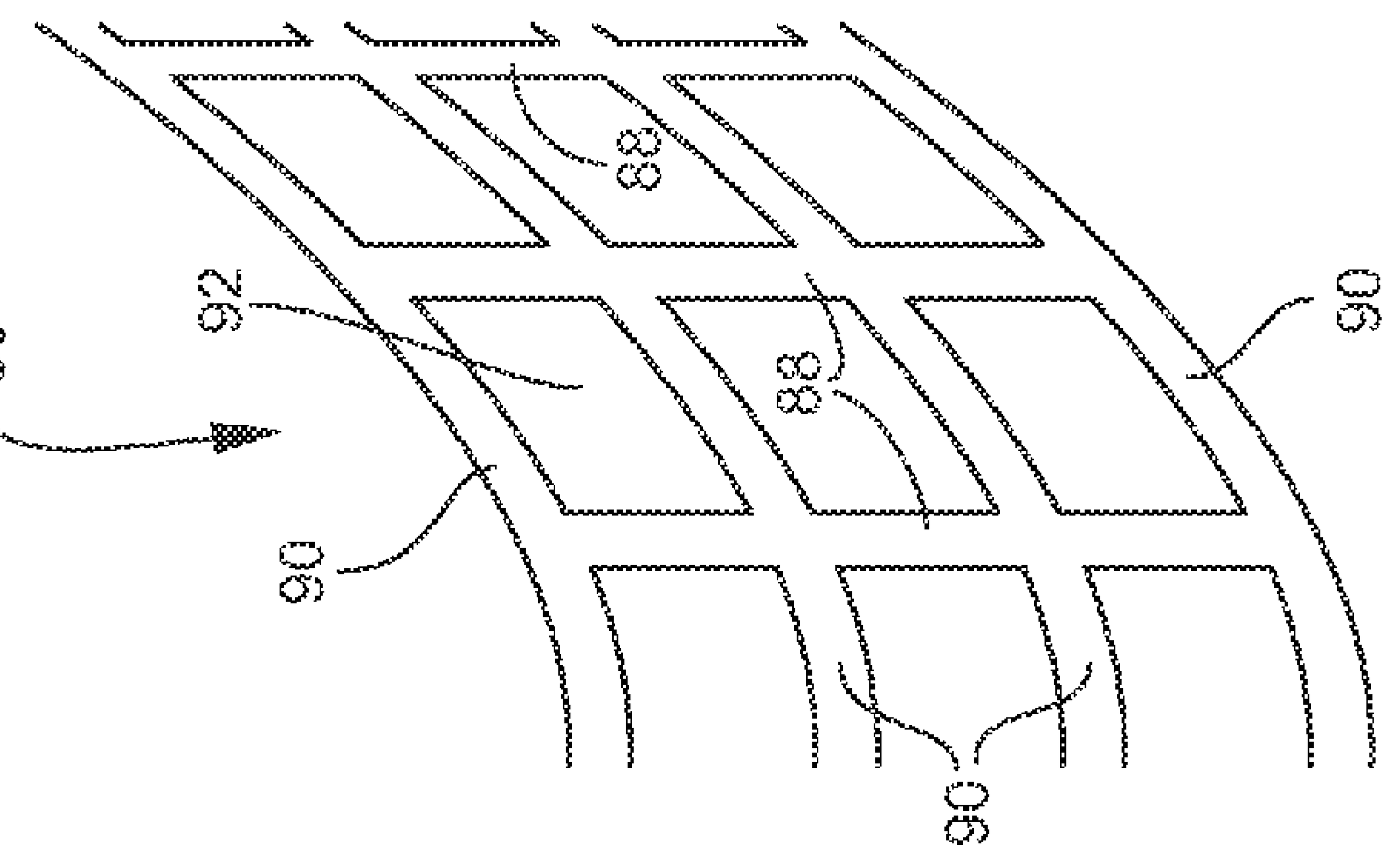

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Fig. 7B

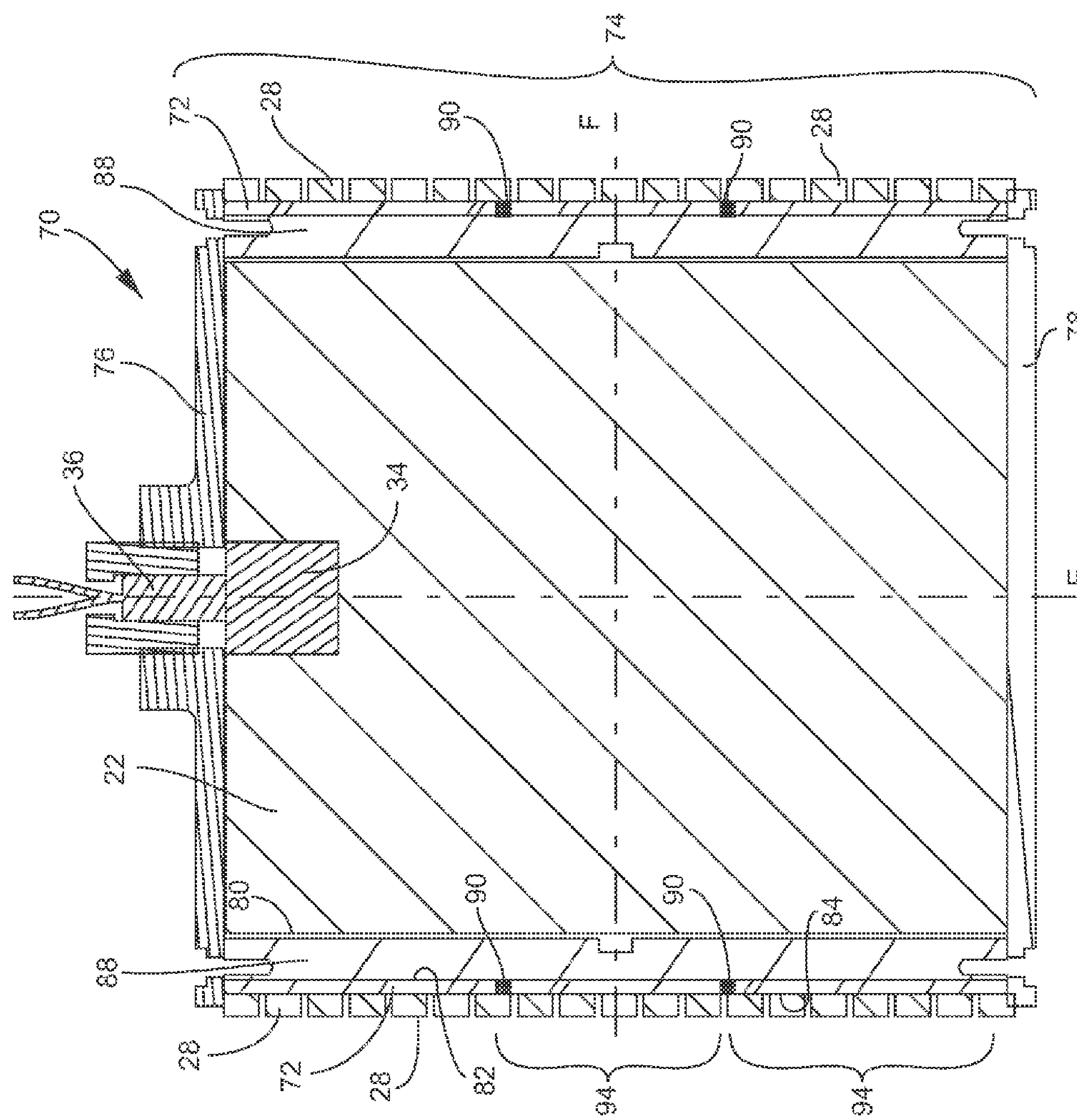
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Fig. 7A

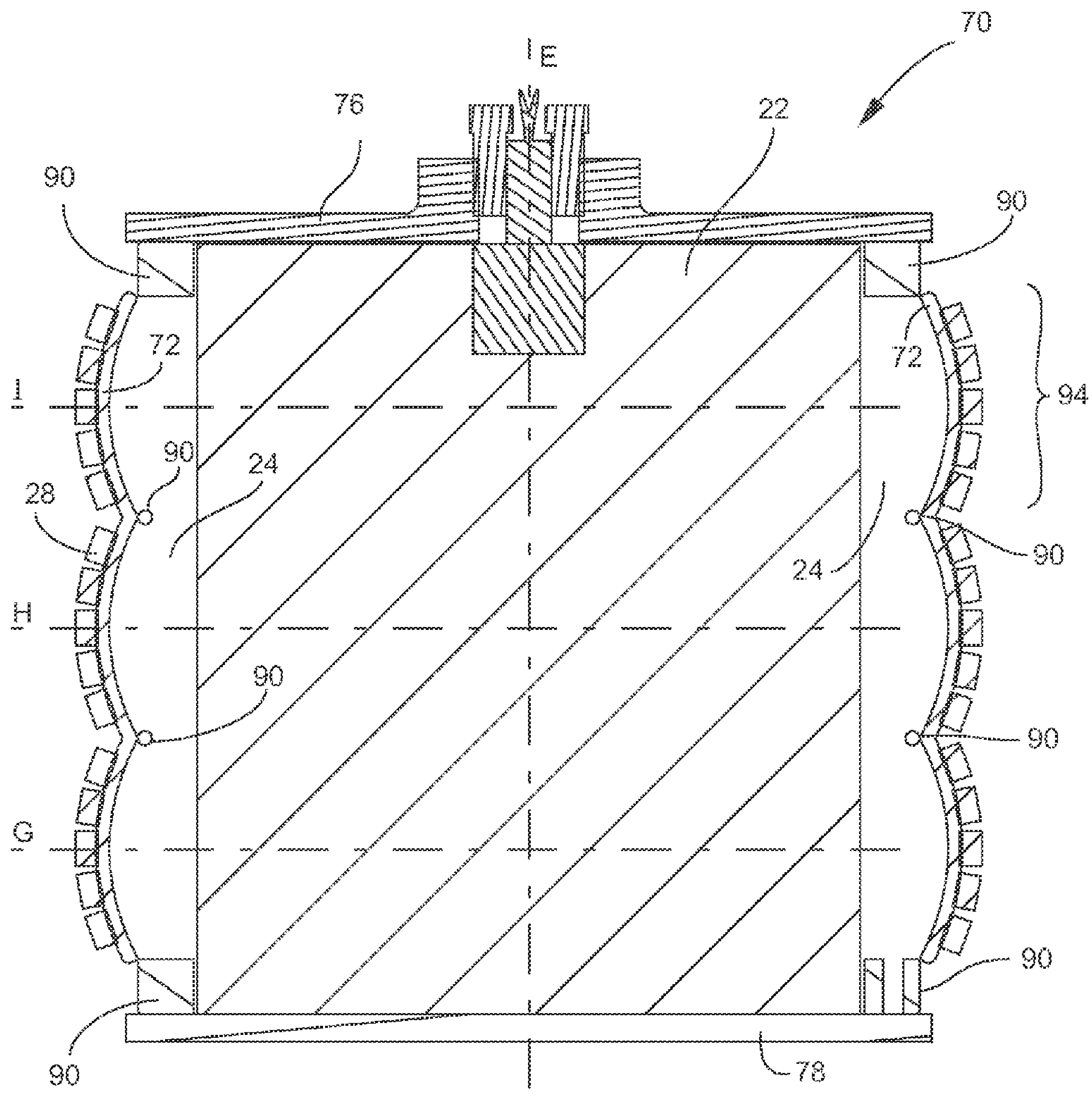

Fig. 8

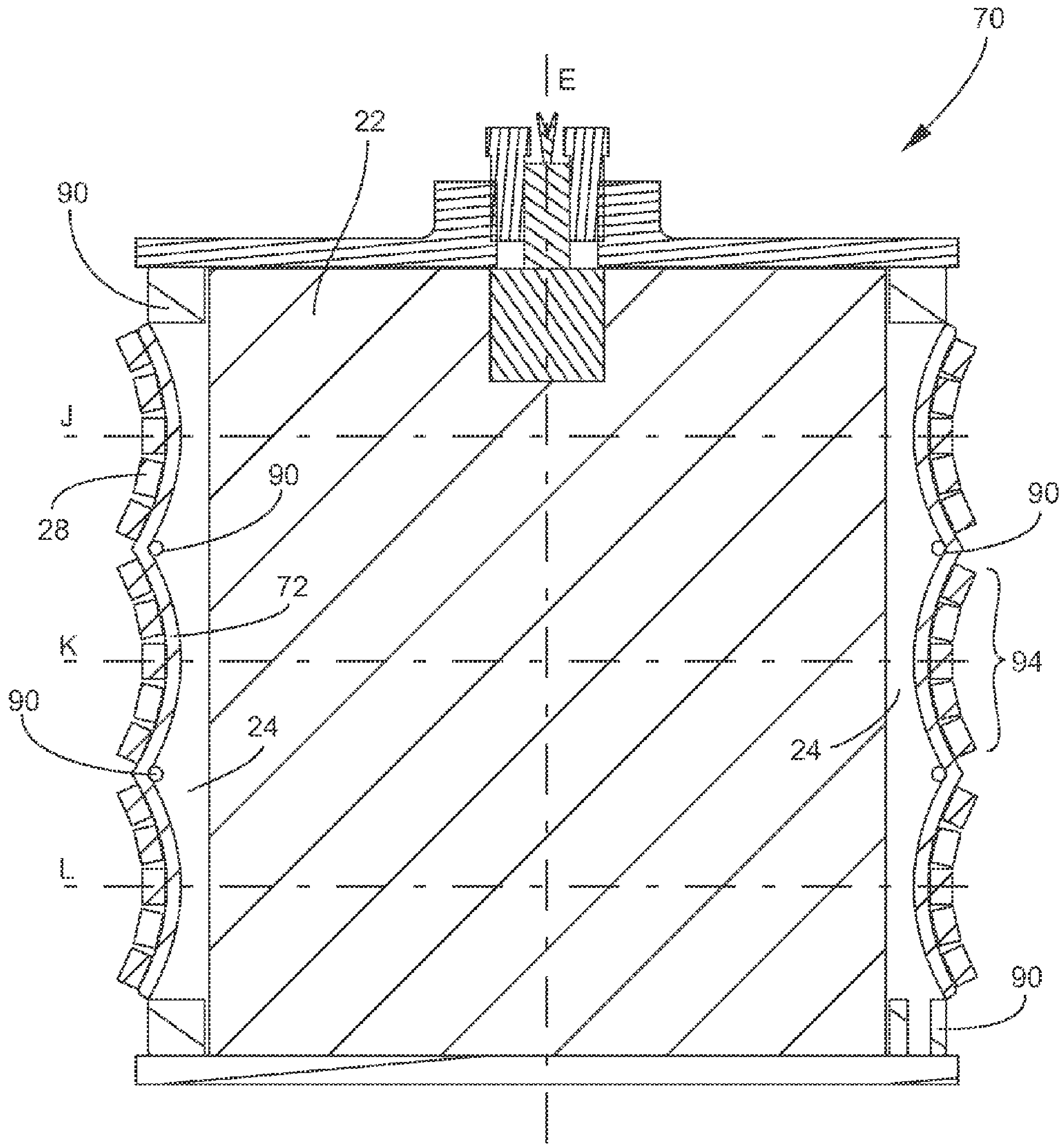

Fig. 9

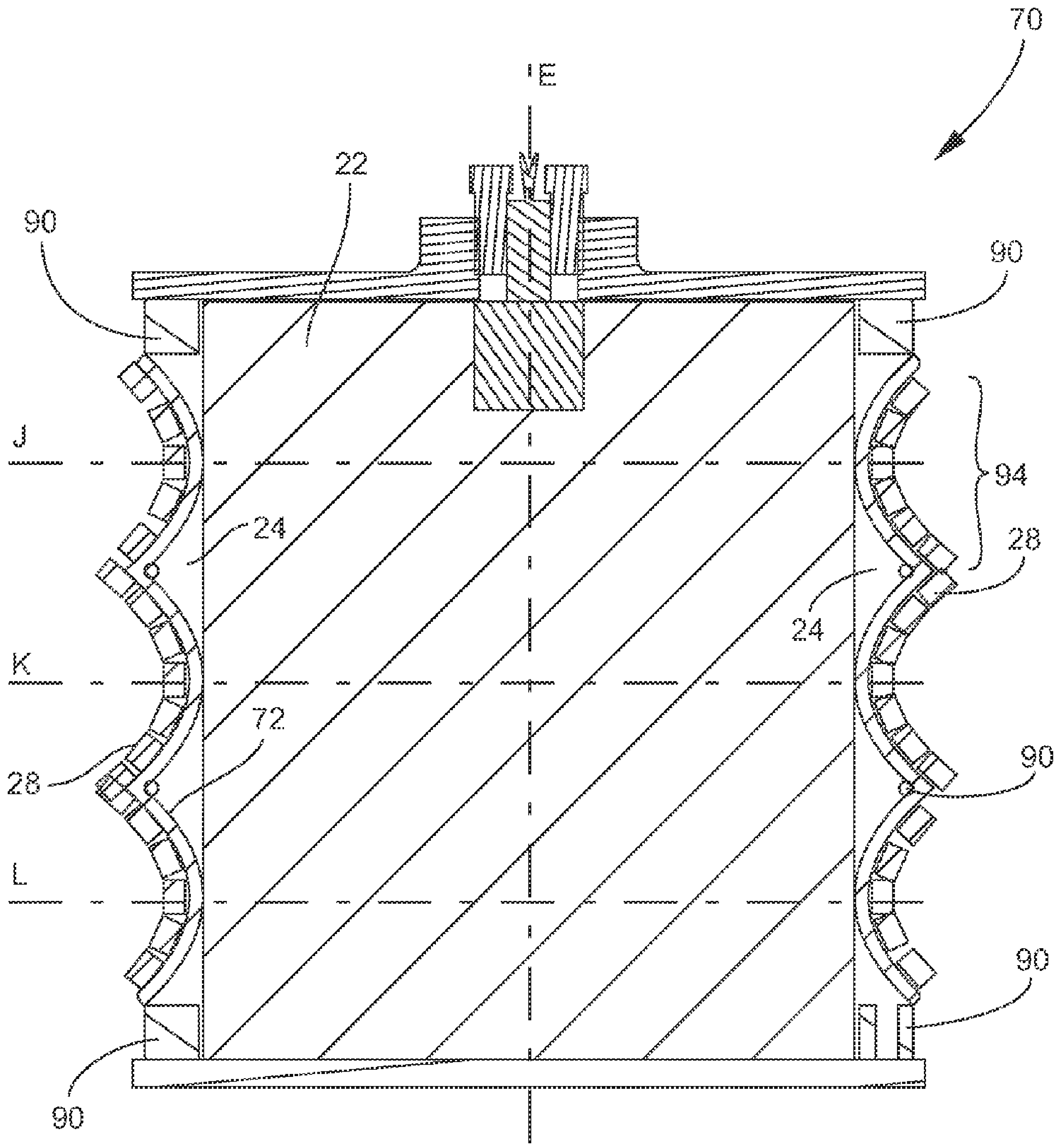

Fig. 10

FRAGMENTATION WARHEAD WITH FLEXIBLE LINER

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of priority of U.S. provisional patent application Ser. No. 61/824,554 filed on May 17, 2013, which is incorporated by reference herein.

STATEMENT OF GOVERNMENT INTEREST

The inventions described herein may be manufactured, used and licensed by or for the United States Government.

BACKGROUND OF THE INVENTION

The invention relates in general to munitions and in particular to fragmentation warheads.

The fragmentation effects of a warhead can be delivered by a variety of known techniques. In some cases, unintended collateral damage may be caused by warhead fragments. A need exists for an apparatus and method to direct or channel the fragmentation effects of a warhead to a targeted area, while simultaneously eliminating excess fragmentation and collateral damage.

SUMMARY OF INVENTION

One aspect of the invention is a fragmentation warhead with a central longitudinal axis and a housing. The housing includes a portion formed of a flexible liner and a portion formed of a rigid material. A high explosive material is disposed in the housing. A fluid is disposed between the high explosive material and the flexible liner. The fluid is contiguous with and bears on an inner surface of the flexible liner. A plurality of rigid fragments or a plurality of explosively formed projectile liners are fixed to an outer surface of the flexible liner opposite the fluid.

The fluid may be an energetic material. The fluid and the high explosive material may be the same viscous material.

In one embodiment, the rigid material portion of the housing may be generally in the shape of a hollow right circular cylinder having one open end and a central longitudinal axis. The flexible liner may be fixed to the perimeter of the one open end. The rigid material portion may include a telescoping portion that moves the flexible liner between concave, neutral, and convex positions. The flexible liner may be symmetric about the central longitudinal axis of the warhead.

In another embodiment, the rigid material portion of the housing may include a pair of opposed end plates and the flexible liner may be fixed to and extend between the pair of opposed end plates to form a side wall of the housing. The side wall of the housing may be movable between concave, neutral, and convex positions by altering a volume of the fluid in the housing.

A framework in the form of a grid may be disposed between the side wall and the high explosive material. The grid may include a plurality of longitudinal members extending between the pair of opposed end plates and a plurality of circumferential members extending around the side wall. The side wall may be fixed to the plurality of longitudinal members and the plurality of circumferential members to form an individually movable sub-curvature for each opening in the grid. The sub-curvatures may be movable between concave, neutral, and convex positions by altering the volume of the fluid in the housing.

Another aspect of the invention is a method that includes providing a warhead having a flexible liner and adjusting a shape of the flexible liner to thereby alter a fragmentation pattern of the warhead.

The step of adjusting may include adjusting the shape of the flexible liner between concave, neutral, and convex positions.

In one embodiment, the step of adjusting includes adjusting the shape of the flexible liner by altering a volume fluid in the warhead.

In another embodiment, the step of adjusting includes translating a telescoping portion of the housing of the warhead.

The invention will be better understood, and further objects, features and advantages of the invention will become more apparent from the following description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily to scale, like or corresponding parts are denoted by like or corresponding reference numerals.

FIG. **1**A is a top view of an embodiment of an end-fired warhead with a flexible liner.

FIG. **1**B is a sectional elevation view along the line **1**B-**1**B of the warhead of FIG. **1**A, with the flexible liner in a neutral position.

FIG. **2** is a sectional elevation view of the warhead of FIG. **1**A with the flexible liner in a convex or divergent position.

FIG. **3** is a sectional elevation view of the warhead of FIG. **1**A with the flexible liner in a concave or convergent position.

FIG. **4** is a sectional elevation view of the warhead of FIG. **1**A with the flexible liner in a more concave position than in FIG. **3**.

FIG. **5**A is a top view of an embodiment of a side-fired warhead with a flexible liner.

FIG. **5**B is a sectional view along the line **5**B-**5**B of the warhead of FIG. **5**A with the flexible liner in a concave or convergent position.

FIG. **6** is a sectional view of the warhead of FIG. **5**A with the flexible liner in a convex or divergent position.

FIG. **7**A is a sectional view of an embodiment of a side-fired warhead having a flexible liner and an internal grid.

FIG. **7**B is a perspective view of a portion of an internal grid.

FIG. **8** is a sectional view of the warhead of FIG. **7**A showing the sub-curvatures in convex or diverging positions.

FIG. **9** is a sectional view of the warhead of FIG. **7**A showing the sub-curvatures in concave or converging positions.

FIG. **10** is a sectional view of the warhead of FIG. **7**A showing the sub-curvatures in more concave positions than in FIG. **9**.

DETAILED DESCRIPTION

A novel fragmentation warhead has a housing formed in part by a rigid material and in part by a flexible liner. The warhead has a central longitudinal axis. An explosive composition, such as a high explosive material, is disposed in the housing. A fluid is disposed in the housing between the explosive material and the flexible liner. The fluid is contiguous with and bears on an inner surface of the flexible liner. A plurality of rigid fragments are fixed to an outer surface of the flexible liner opposite the fluid. The rigid fragments are propelled at a high velocity by energy produced when the explosive material is initiated.

In some embodiments, a plurality of explosively formed projectile (EFP) liners may be used in lieu of the plurality of rigid fragments. That is, a plurality of EFP liners may be fixed to the outer surface of the flexible liner, rather than a plurality of rigid fragments.

In some embodiments, the fluid and the explosive material may be the same viscous material.

In some other embodiments, the fluid and the high explosive material may be different materials. By way of example only, the fluid may be oil and the explosive material may be a solid material.

The configuration or shape of the flexible liner with the fragments (or EFP liners) fixed thereto may be adjusted or changed prior to reaction of the explosive material. Adjustment of the flexible liner changes the cone angle of the fragment pattern. The fragment pattern may be adjusted in a continuous manner from a diverging pattern to a linear or neutral pattern to a converging pattern.

In some embodiments, the fragments may be propelled in directions that are parallel or acutely angled with respect to the central longitudinal axis of the warhead. These embodiments are "end-fired" warheads. In the end-fired warheads, adjustment of the shape of the flexible liner may be enabled by altering the volume of fluid in the warhead or by translating a telescoping portion of the rigid part of the housing.

In some other embodiments, the fragments may be propelled in directions that are generally radial with respect to the central longitudinal axis of the warhead. These embodiments are "side-fired" warheads. In the side-fired warheads, adjustment of the shape of the flexible liner may be enabled by altering the volume of fluid in the warhead.

The novel warhead may be used in a variety of ways. By way of example only, the warhead may be placed by hand and remotely detonated, or the warhead may be launched from a gun tube. In some embodiments, the flexible liner may be adjusted manually. In other embodiments, the flexible liner may be adjusted by a remotely-operated mechanism.

FIGS. **1-4** are views of an embodiment of an end-fired fragmentation warhead. FIGS. **5-10** are views of embodiments of side-fired fragmentation warheads.

FIG. **1**A is a top view of an embodiment of an end-fired warhead **10** with a flexible liner **12** in a neutral position. FIG. **1**B is a sectional elevation view of the end-fired warhead **10** of FIG. **1**A. Warhead **10** has a central longitudinal axis A. The housing **14** of warhead **10** includes flexible liner **12** and a rigid portion. The flexible liner **12** may be made of, for example, neoprene. The rigid portion includes an end cap **16**, a cylinder **18** fixed to end cap **16**, and a telescoping portion **20**. The rigid portion may be made of, for example, steel.

Telescoping portion **20** is translatable with respect to cylinder **18** in the direction of axis A. A sealing ring **38** for sealing fluid may be disposed between telescoping portion **20** and cylinder **18**. The rigid portion of housing **14** is generally in the shape of a hollow right circular cylinder having a central longitudinal axis B and an open end which is closed by flexible liner **12**. The flexible liner **12** is fixed to the perimeter of the telescoping portion **20** and may be symmetric about axes A and B. Axes A and B are coincident.

An explosive material, such as a high explosive material **22**, is disposed in housing **14**. A fluid **24** is disposed between high explosive material **22** and flexible liner **12**. Fluid **24** is contiguous with and bears on an inner surface **26** of the flexible liner **12**. Fluid **24** functions as a shock transition material. Fluid **24** may be, for example, oil, such as hydraulic oil. A plurality of rigid fragments **28** are fixed to an outer surface **30** of the flexible liner **12** opposite the fluid **24**. Fragments **28** may be made of, for example, steel or other materials. Fragments **28** may be fixed to liner **12** by, for example, gluing. As mentioned previously, a plurality of mini-EFP liners (not shown) may be used in lieu of fragments **28**.

In the embodiment shown, the fluid **24** is separated from explosive **22** by a membrane or plate **32**. However, fluid **24** and explosive **22** may be the same material, for example, a viscous explosive material, in which case membrane **32** is not needed.

An explosive booster **34** may be disposed in explosive **22** and a detonator **36** disposed adjacent booster **34**. By way of example only, detonator **36** may be activated by a wireless electromagnetic signal or a known warhead fuze.

Telescoping portion **20** may be translated with respect to cylinder **18** in the direction of axis A to thereby alter the shape or position of flexible liner **12** between concave, neutral, and convex positions. In FIG. **1**B, flexible liner **12** is in a neutral position, that is, liner **12** is planar and horizontal. When explosive **22** initiates, fragments **28** will generally be propelled in directions parallel to axis A.

In FIG. **2** and as compared to FIG. **1**B, telescoping portion **20** has been translated downward with respect to cylinder **18** thereby causing fluid **24** to move liner **12** into a convex or divergent position. When explosive **22** initiates, fragments **28** will generally be propelled in directions that diverge from axis A.

In FIG. **3** and as compared to FIG. **1**B, telescoping portion **20** has been translated upward with respect to cylinder **18** thereby causing liner **12** to assume a concave or convergent shape. When explosive **22** initiates, fragments **28** will generally be propelled in directions that converge toward axis A.

In FIG. **4** and as compared to FIG. **3**, telescoping portion **20** has been translated further upward with respect to cylinder **18** thereby causing liner **12** to assume a more concave or convergent shape than in FIG. **3**. When explosive **22** initiates, fragments **28** will generally be propelled in directions that sharply converge toward axis A and may form a focused fragment array (FFA).

Telescoping portion **20** may be translated with respect to cylinder **18** by hand or by a machine, using a variety of known techniques and mechanisms. For example, telescoping portion **20** and cylinder **18** may be threadingly engaged and rotated with respect to each other by hand or by well-known mechanisms, such as an electric motor drive. The translating mechanism may be placed in a gun-launched projectile with warhead **10** so that translation of portion **20** may occur after the projectile is loaded in a launching tube or during the flight of the projectile.

In the embodiment of warhead **10** shown in FIGS. **1-4**, the shape of liner **12** is varied by translating telescoping portion **20** with respect to cylinder **18**. In a variation of warhead **10**, telescoping portion **20** and cylinder **18** may form a single unitary side wall without a translating portion. In this variation, the volume of fluid **24** in warhead **10** may be increased or decreased to thereby create the variations in the shape of liner **12** shown in FIGS. **1**B and **2-4**. Fluid **24** may be added by through a fluid fitting (not shown) in the unitary side wall. A pump connected to a reservoir may be used to add or remove fluid **24** from the warhead **10**, depending on the desired configuration of liner **12** (i.e., neutral, convex, concave). The pump may be manually operated, or a pump/motor combination and reservoir may be disposed in a projectile with warhead **10** to enable changes in the shape of liner **12** after the projectile is loaded in a launch tube or while the projectile is in flight.

FIG. **5**A is a top view of an embodiment of a side-fired warhead **50** having a central longitudinal axis C. FIG. **5**B is a sectional view taken along the line **5**B-**5**B of FIG. **5**A showing the flexible liner **52** in a concave or convergent position. The housing **54** of warhead **50** includes flexible liner **52** and a rigid portion. The rigid portion includes a pair of opposed end plates **56**, **58**. Flexible liner **52** is fixed to and extends between the opposed end plates **56**, **58**. Liner **52** forms a side wall of the housing **54**. Preferably, liner **52** extends circumferentially 360 degrees to form the complete side wall of the housing. The flexible liner **52** may be symmetric about axis C.

Explosive material **22** is disposed in housing **54**. A fluid **24** is disposed between explosive material **22** and flexible liner **52**. Fluid **24** is contiguous with and bears on an inner surface **62** of the flexible liner **52**. Fluid **24** functions as a shock transition material. Fluid **24** may be, for example, oil, such as hydraulic oil. A plurality of rigid fragments **28** (or mini-REP liners) are fixed to an outer surface **64** of the flexible liner **52** opposite the fluid **24**. Fragments **28** may be made of, for example, steel or other materials

In the embodiment of warhead **50** shown, the fluid **24** is separated from explosive **22** by a cylindrical membrane or plate **60**. However, fluid **24** and explosive **22** may be the same material, for example, a viscous explosive material, in which case membrane **60** is not needed. If fluid **24** and explosive **22** are both a viscous energetic material, then an internal supporting structure (not shown) would be needed.

An explosive booster **34** may be disposed in explosive **22** and a detonator **36** disposed adjacent booster **34**. By way of example only, detonator **36** may be activated by a wireless electromagnetic signal or a known warhead fuze.

The volume of fluid **24** in warhead **50** may be increased or decreased to thereby create variations in the shape of liner **52**. Liner **52** is in a concave or convergent configuration in FIG. **5**B. When explosive **22** is initiated, fragments **28** will be propelled generally in directions that converge toward axis D, which is normal to axis C.

Adding additional fluid **24** to warhead **50** causes liner **52** to assume a neutral configuration (not shown) wherein liner **52** has a shape of a right circular cylinder centered on axis C. In the neutral configuration of liner **52**, fragments **28** will be propelled in directions parallel to axis D.

From the neutral configuration of liner **52**, the addition of more fluid **24** causes liner **52** to assume a convex or divergent configuration shown in FIG. **6**. When explosive **22** is initiated, fragments **28** will be propelled generally in directions that diverge away from axis D.

Fluid **24** may be added through a fluid fitting (not shown) in one of the end plates **56**, **58**. A pump connected to a reservoir may be used to add or remove fluid **24** from warhead **50**, depending on the desired configuration of liner **52** (i.e., neutral, convex, concave). The pump may be manually operated, or a pump/motor combination and reservoir may be disposed in a projectile with warhead **50** to enable changes in the shape of liner **52** after the projectile is loaded in a launch tube or while the projectile is in flight.

Other embodiments of novel side-fired warheads are similar to warhead **50**, but include an internal rigid grid. The flexible liner is fixed to the internal grid to form a plurality of individually deformable "sub-curvatures." FIG. **7**A is a sectional view of an embodiment of a side-fired fragmentation warhead **70** with an internal rigid grid. The internal grid **86** alone is shown in a partial perspective view in FIG. **7**B. Warhead **70** includes a housing **74** formed by pair of rigid end plates **76**, **78** and a flexible liner **72**. Warhead **70** has a central longitudinal axis E.

Liner **72** forms the side wall of warhead **70**. Fragments **28** are fixed to an outer surface **84** of liner **72**. Explosive material **22** is disposed in the housing **74**. An explosive booster **34** may be disposed in explosive **22** and a detonator **36** disposed adjacent booster **34**. By way of example only, detonator **36** may be activated by a wireless electromagnetic signal or a known warhead fuze.

A framework in the form of an internal grid **86** is disposed between the liner **72** and the explosive material **22**. The grid **86** includes a plurality of longitudinal members **88** that extend between the pair of opposed end plates **76**, **78** and a plurality of circumferential members **90** that extend circumferentially around the warhead **70**. The circumferential members **90** are fixed to the longitudinal members **88** at their points of intersection. The plurality of longitudinal members **88** may be circumferentially equally spaced. The plurality of circumferential members **90** may be longitudinally equally spaced. The members **88**, **90** may be made of a metal, for example, steel.

Liner **72** is fixed to the plurality of longitudinal members **88** and the plurality of circumferential members **90** to form an individual, flexible sub-curvature **94** for each opening **92** (FIG. 7B) in the grid. Not seen in FIG. **7**A is the fluid **24** (see FIGS. **8**-**10**) disposed between liner **72** and explosive **22**. In FIG. **7**A, the liner **72** is in the neutral position wherein the fragments **28** will be propelled in directions generally parallel to radial axes which are normal to axis E, such as radial axis F.

FIG. **8** is a sectional view of the warhead **70** of FIG. **7**A showing the sub-curvatures **94** in convex or diverging positions. An increase in the volume of fluid **24** in warhead **70** causes the sub-curvatures **94** to move from the neutral positions of FIG. **7**A to the diverging positions of FIG. **8**. When explosive **22** in warhead **70** of FIG. **8** initiates, fragments **28** will be propelled in directions that diverge from radial axes which are normal to axis E, such as radial axes G, H and I.

FIG. **9** is a sectional view of the warhead of FIG. **7**A showing the sub-curvatures **94** in concave or converging positions. A decrease in the volume of fluid **24** in warhead **70** causes the sub-curvatures **94** to move from the neutral positions of FIG. **7**A to the converging positions of FIG. **9**. When explosive **22** in warhead **70** of FIG. **9** initiates, fragments **28** will be propelled in directions that converge toward radial axes which are normal to axis E, such as radial axes J, K and L.

FIG. **10** is a sectional view of the warhead **70** of FIG. **7**A showing the sub-curvatures in more concave positions than in FIG. **9**. A decrease in the volume of fluid **24** in warhead **70** causes the sub-curvatures **94** to move from the concave positions of FIG. **9** to the more concave positions of FIG. **10**. When explosive **22** in warhead **70** of FIG. **10** initiates, fragments **28** will be propelled in directions that diverge from radial axes which are normal to axis E, such as radial axes J, K and L.

While the invention has been described with reference to certain embodiments, numerous changes, alterations and modifications to the described embodiments are possible without departing from the spirit and scope of the invention as defined in the appended claims, and equivalents thereof.

What is claimed is:

1. A fragmentation warhead with a central longitudinal axis, comprising:

a housing having a portion formed of a flexible liner and a portion formed of a rigid material;

a high explosive material disposed in the housing;

a fluid disposed between the high explosive material and the flexible liner, the fluid being contiguous with and bearing on an inner surface of the flexible liner; and, where a wall of the housing is movable between concave, neutral, and convex positions by altering the volume of said fluid; and,

one of a plurality of rigid fragments and a plurality of explosively formed projectile liners fixed to an outer surface of the flexible liner opposite the fluid.

2. The warhead of claim **1**, wherein the fluid is a second high explosive material.

3. The warhead of claim **2**, wherein the high explosive material and the second high explosive material are a same viscous material.

4. The warhead of claim **1**, wherein the fluid is oil.

5. The warhead of claim **1**, wherein the rigid material portion of the housing is generally in a shape of a hollow right circular cylinder having one open end and a second central longitudinal axis, the flexible liner being fixed to a perimeter of the one open end, and the second central longitudinal axis being coincident with the central longitudinal axis of the warhead.

6. The warhead of claim **5**, wherein the rigid material portion includes a telescoping portion that moves the flexible liner between concave, neutral, and convex positions.

7. The warhead of claim **6**, wherein the flexible liner is symmetric about the central longitudinal axis of the warhead.

8. The warhead of claim **1**, wherein the rigid material portion of the housing includes a pair of opposed end plates and the flexible liner is fixed to and extends between the pair of opposed end plates to form a side wall of the housing, the side wall of the housing being movable between concave, neutral, and convex positions by altering a volume of the fluid in the housing.

9. The warhead of claim **8**, wherein the side wall formed by the flexible liner is a 360 degree side wall.

10. The warhead of claim **9**, further comprising a framework in the form of a grid disposed between the side wall and the high explosive material, the grid including a plurality of longitudinal members extending between the pair of opposed end plates and a plurality of circumferential members extending around the side wall.

11. The warhead of claim **10**, wherein the plurality of longitudinal members are circumferentially equally spaced.

12. The warhead of claim **11**, wherein the plurality of circumferential members are longitudinally equally spaced.

13. The warhead of claim **12**, wherein the side wall is fixed to the plurality of longitudinal members and the plurality of circumferential members to form an individually movable sub-curvature for each opening in the grid.

14. The warhead of claim **13**, wherein the sub-curvatures are movable between concave, neutral, and convex positions by altering the volume of the fluid in the housing.

15. A method, comprising:

providing the warhead of claim **1**; and

adjusting a shape of the flexible liner to thereby alter a fragmentation pattern of the warhead.

16. The method of claim **15**, wherein the step of adjusting includes adjusting the shape of the flexible liner between concave, neutral, and convex positions.

17. The method of claim **15**, wherein the step of providing includes providing the warhead with the rigid material portion of the housing generally in a shape of a hollow right circular cylinder having one open end and a second central longitudinal axis, and with the flexible liner fixed to a perimeter of the one open end, and with the second central longitudinal axis coincident with the central longitudinal axis of the warhead.

18. The method of claim **17**, wherein the step of adjusting includes adjusting the shape of the flexible liner by altering a volume of the fluid.

19. The method of claim **17**, wherein the step of providing includes providing the rigid material portion with a telescoping portion and the step of adjusting includes translating the telescoping portion.

20. A fragmentation warhead with a central longitudinal axis, comprising:

a housing having a portion formed of a flexible liner and a portion formed of a rigid material;

a high explosive material disposed in the housing;

a fluid disposed between the high explosive material and the flexible liner, the fluid being contiguous with and bearing on an inner surface of the flexible liner; and one of a plurality of rigid fragments and a plurality of explosively formed projectile liners fixed to an outer surface of the flexible liner opposite the fluid, wherein the rigid material portion of the housing includes a pair of opposed end plates and the flexible liner is fixed to and extends between the pair of opposed end plates to form a side wall of the housing, the side wall of the housing being movable between concave, neutral, and convex positions by altering a volume of the fluid in the housing, and wherein the side wall formed by the flexible liner is a 360 degree side wall, and further comprising a framework in the form of a grid disposed between the side wall and the high explosive material, the grid including a plurality of longitudinal members extending between the pair of opposed end plates and a plurality of circumferential members extending around the side wall, wherein the plurality of longitudinal members are circumferentially equally spaced.

21. The warhead of claim **20**, wherein the plurality of circumferential members are longitudinally equally spaced.

22. The warhead of claim **21**, wherein the side wall is fixed to the plurality of longitudinal members and the plurality of circumferential members to form an individually movable sub-curvature for each opening in the grid.

23. The warhead of claim **22**, wherein the sub-curvatures are movable between concave, neutral, and convex positions by altering the volume of the fluid in the housing.

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